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A Parametric Study of an Excimer Pumped Raman Shifter for Lidar Applications

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MASTER

Abstract

High average power UV laser sources are needed for many remote sensing applications such as Raman, fluorescence, and differential absorption lidars. We are currently developing an excimer-pumped, wavelength flexible Raman shifter for lidar applications.

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Summary

We are currently developing a high average power, wavelength flexible, UV laser system for lidar applications. High average power UV laser sources are needed for many remote sensing applications such as Raman, fluorescence, and differential absorption (DIAL) lidars. While the high pulse energy, high average power, and UV spectral output offered by excimer lasers makes them an excellent choice for most applications, the particular wavelengths covered by these lasers (248, 308 and 351 nm) are too restrictive for many missions of current importance.

Our efforts have focused on the development of a KrF excimer-based, Raman-shifted, solar blind Raman lidar for daytime water vapor profile measurements. Raman lidar measurements of daytime tropospheric water vapor profiles are limited by the difficulty of detecting the weak Raman backscattered signal against the large solar

background, a problem overcome to date only to an extent by operating in the solar blind region of the spectrum. Thus, while Raman lidar techniques have demonstrated the ability to accurately and routinely determine water vapor profiles at night up to 5-10 km, much lower values (from <1 km to a maximum of about 1.3 km) have been achieved in the daytime. This range may be extended by operating at higher pulse energies and at an optimum wavelength. The selection of the optimum wavelength is based on a compromise between absorption by intervening ozone and reduction of the background sky radiance. Independent model calculations suggest that the optimum wavelength for daytime operation is roughly 255-265 nm. This wavelength range places the water vapor Raman return at approximately 281-293 nm, which is near the ozone absorption edge at 295 nm. Although a near optimum wavelength of 266 nm can be achieved by a quadrupled Nd:YAG laser, the corresponding average powers and conversion efficiencies are typically low, resulting in these systems being less desirable than an excimer-based system. A Raman shifted excimer laser offers the potential of wavelength optimized operation and higher average powers,[1] although gas recirculation in the Raman cell may be required for high repetition rates.

After a review of potential candidate species for Raman shifting the 248-nm output of the KrF laser to a more optimum wavelength, we have selected nitrogen for initial study, although other gases that provide different wavelengths will also be studied. While a significant literature exists on the nitrogen Raman spectrum, scattering cross sections, and collisional linewidths, very little work has been done on the use of nitrogen gas as a Raman shifting medium.

The design of an efficient nitrogen Raman cell is difficult because of its relatively low spontaneous Raman cross section. In addition, the effective Raman linewidth of nitrogen is large (~ 2 cm^{-1}), thus further lowering the stimulated Raman gain. Therefore, optimization of adjustable parameters such as the cell length, cell pressure, pump power, pump focus and beam quality are essential. The Raman conversion efficiency can be enhanced further by injecting the Raman amplifier with the forward or backward Stokes waves from a seed generator.[2] By injecting this seed radiation into a well-collimated amplifier the pump energy can be efficiently converted into one or several Stokes orders. A parametric study of experimental variables such as cell pressure, pump power, and pump focus forms the basis of this work, which also encompasses a comparison of single-pass amplification versus seeded and self-seeded[3] configurations.

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